NASA PGG: NAG5-13172
Title: Geophysics of Martian Periglacial Processes
PI: Dr. Michael T. Mellon, University of Colorado

## PROJECT SUMMARY

### *SCIENTIFIC OBJECTIVES:*

- Through the examination of small-scale geologic features potentially related to water and ice in the martian subsurface (specifically small-scale polygonal ground and young gully-like features), determine the state, distribution and recent history of subsurface water and ice on Mars.
- To refine existing models and develop new models of near-surface water and ice, and develop new insights about the nature of water on Mars as manifested by these geologic features.
- Through an improved understanding of potentially water-related geologic features, utilize these features in addressing questions about where to best search for present day water and what space craft may encounter that might facilitate or inhibit the search for water.

### *WORK PLAN IN BRIEF:*

To realize these objectives we proposed the following activities:

1. Develop a database of specific potentially water-related geologic features (small-scale polygonal patterns and gully-like features), including their properties, and their geographic dependencies.
2. Utilize the observational database to test current models of polygons and gullies.
3. Refine and further develop models of polygon and gully formation in light of these observations.

## RECENT PROGRESS

During the past year we have made progress in areas of cataloging and analyzing martian gullies and analysis of antarctic permafrost polygons for comparison to martian forms. We have written papers and abstracts on gullies with graduate student (Heldmann).

- Papers:

  Heldmann, J. L. and M. T. Mellon, Observations of martian gullies and constraints on potential formation mechanisms, *Icarus*, in press (2004)

  Heldmann, J. L., O. B. Toon, W. H. Pollard, M. T. Mellon, J. Pitlick, C. P. McKay, and D. T. Anderson, Formation of martian gullies by the flow of simultaneously freezing and boiling liquid water, submitted to *Nature* (2003)

- Abstracts:

  Heldmann, J. L. and M. T. Mellon, Gullies on Mars and constraints imposed by Mars Global Surveyor data, *NASA Astrobiology Institute Meeting,* Tempe, AZ (2003)

  Heldmann, J. L., M. T. Mellon, W. H. Pollard, D. T. Anderson, and C P. McKay, The association of liquid water springs with permafrost regions on Earth and Mars, *Amer. Geophys. Union Fall Meeting,* San Francisco, CA, (2003)

*MARTIAN GULLIES:*

We have made significant progress in analysis of martian gullies that has resulted in two papers (one in press and one submitted). On this topic we (myself and graduate student Heldmann) searched the Mars Orbiter Camera (MOC) database for images containing gully-like features with clear, alcove-channel-apron morphology as described by Malin and Edgett (2000). We specifically examined the region between 30° and 70° south latitude and found 139 images that met our criteria. Of these 106 could be spatially correlated with Mars Orbiter Laser Altimeter (MOLA) data and were examined further (e.g., Figure 1). Parameters were measured including apparent source depth and distribution, vertical and horizontal dimensions, slopes, orientations, and present-day thermophysical characteristics that affect local ground temperatures.

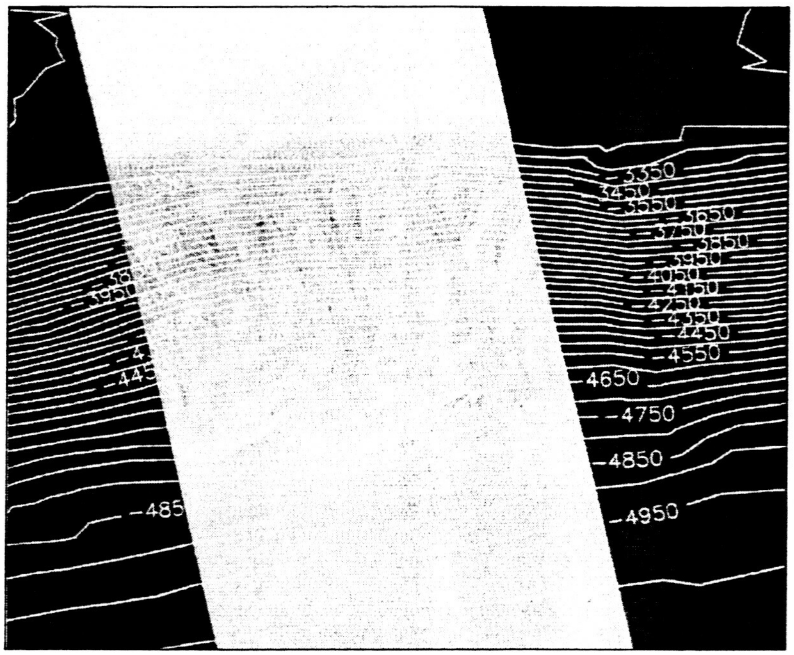



*Figure 1: Elevation contour map derived from multiple ground tracks of MOLA data overlaid on a portion of MOC image M07-03139. Contours are at 50 m intervals with respect to the MOLA datum. The width of the MOC image is 2.85 km.*

Results are described in Heldmann and Mellon (2004). In brief, we found that the number of gully systems steadily declines poleward of 30° S, reaches a minimum value between 60°-63° S, and then again rises poleward of 63° S. All gully alcove heads occur within the upper one-third of the slope encompassing the gully and the alcove bases occur within the upper two-thirds of the slope. Also, the gully alcove heads occur typically within the first 200 meters of the overlying ridge with the exception of gullies equatorward of 40°S where some alcove heads reach a maximum depth of 1000 meters. Additionally, while gullies exhibit complex slope orientation trends, gullies are found on all slope orientations at all of the latitudes studied. Assuming thermal conductivities derived from TES measurements as well as modeled surface temperatures, we find that 79% of the gully alcove bases lie at depths where subsurface temperatures should be greater than 273 K. Interestingly, most of the gully alcoves are outside the temperature-pressure phase stability required for liquid $CO_2$.

Based on a comparison of measured gully features with predictions from the various models of gully formation, we find that the models involving carbon dioxide, melting ground ice in the upper few meters of the soil, dry landslide, and surface snowmelt are the least likely to describe the formation of the martian gullies. Although some discrepancies still exist between prediction and observation, the shallow and deep aquifer models remain as the most plausible theories. Interior processes involving subsurface fluid sources are generally favored over exogenic processes such as wind and snowfall for explaining the origin of the martian gullies.

***POLYGON MODELING:***

We have also made important progress in our permafrost thermal-contraction polygon modeling efforts. Work is ongoing in logging, collecting, and calibrating antarctic field data of polygon temperatures and crack strains. I have been working with Collaborator Bernard Hallet on getting these data calibrated and validated. Multiple years of field data are now available. Preliminary analysis shows the strain data and temperature oscillations are anti-correlated as would be expected from thermal contraction theory (see Figures 2 and 3) and that net crack growth is observed from year to year.

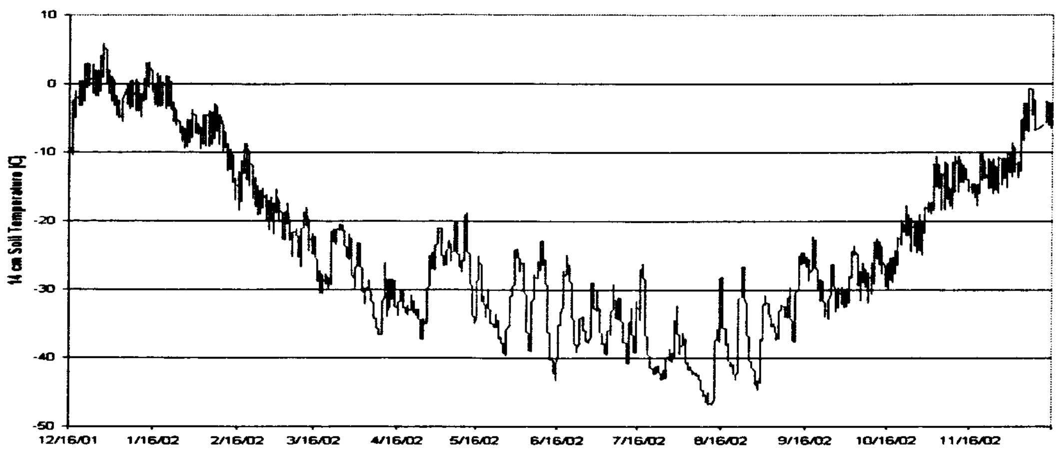



*Figure 2: Antarctic soil temperatures at 14 cm below the soil surface in central Beacon Valley in the Antarctic Dry Valleys. Subsurface temperature oscillations drive thermal contraction and expansion of ice-cemented soils, which in turn drives stresses and strains in the permafrost. Data shown were collected during the 2002 calendar year.*

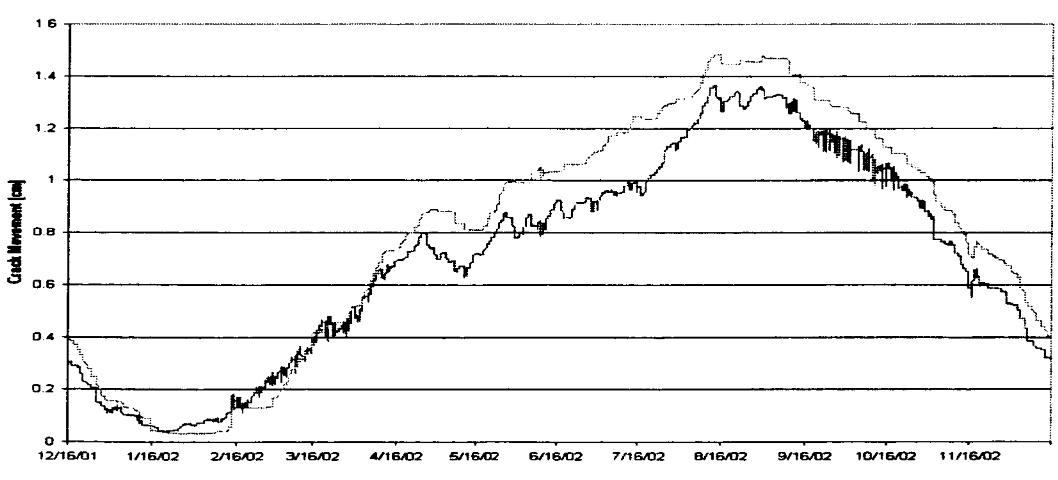



*Figure 3 Antarctic polygon crack strain in the same location as the temperature data in Figure 2. Red and Blue lines indicate strains across two separate cracks of the same polygon.*

## PLANNED ACTIVITIES FOR THE COMING YEAR

### *MORE ON MARTIAN GULLIES:*

We plan to continue working with Heldmann (graduated and now an NRC post-doc at NASA Ames) on gully analysis focusing on gullies in the northern hemisphere and gully morphology analysis looking for clues of potential multiple formation mechanisms.

### *MORE ON ANTARCTIC AND MARTIAN POLYGONS:*

In the coming year we will focus more on studies of permafrost polygons. The first part of this activity will be completion of analysis of antarctic thermal-contraction polygons. In addition to better understanding terrestrial polygons, results from the antarctic study will be used to tune and validate the numerical models for application to Mars. Following the antarctic study will be a study of martian polygons.

Antarctic - Polygon temperature and strain data for three field sites will be analyzed using a previously developed TECTON-based finite-element model of polygon formation and development. The three field sites provide an opportunity to study different permafrost rheologies. At two of the sites polygons are underlain by ice-cemented soil and the third is underlain by dirty ice. Difference in the response of these materials to contraction stress can be evaluated and used to tune the model rheology for various martian permafrost conditions. These results will then be published.

Mars – The finite-element model will the be used to study martian polygons. Specific areas of interest are the polygon size (versus latitude, geographic region, and local climate conditions) and the expected formation of surface relief (troughs and ridges). Subsurface temperatures from a standard Mars thermal model (e.g., Mellon et al., 2000) will be used as input to the finite-element model. Climate conditions will be varied in this thermal model to simulate variations in latitude, soil properties, ice-table depth, etc. Resulting stress fields will be used to evaluate crack spacing. Surface relief will be evaluated by examining net strains from many seasonal model cycles. These results will then be published.

### *REFERENCES:*

Heldmann, J. L. and M. T. Mellon, Observations of martian gullies and constraints on potential formation mechanisms, *Icarus*, in press (2004)

Malin, M. C. and K. S. Edgett, Evidence for recent groundwater seepage and surface runoff on Mars. Science 288, 2330-2335 (2000)

Mellon, M. T., B. M. Jakosky, H. H. Kieffer, and P. R. Christensen, High-resolution thermal inertia mapping from the Mars Global Surveyor Thermal Emission Spectrometer. Icarus 148, 437-455 (2000)

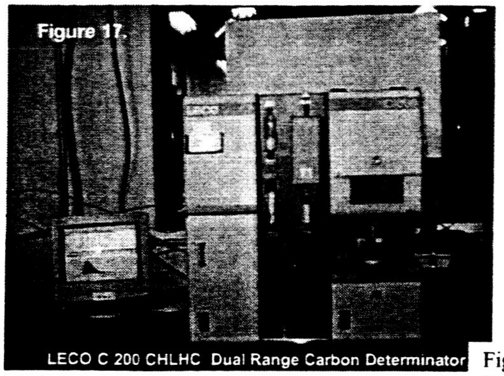
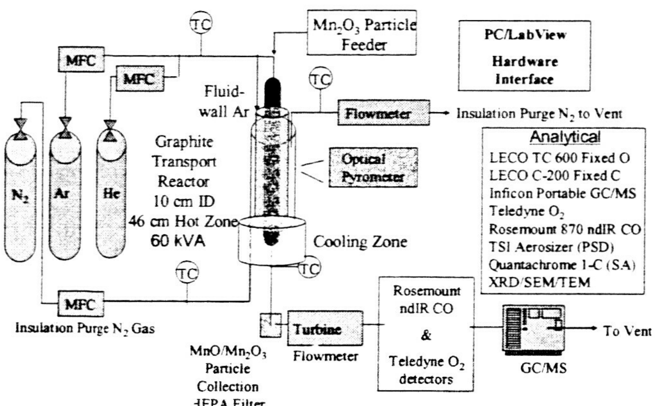


Figure 17.

LECO C 200 CHLHC Dual Range Carbon Determinator

Figure 18. Schematic of University of Colorado Lab Graphite Transport Reactor System (T = 2673 K Capability; Completely Instrumented))



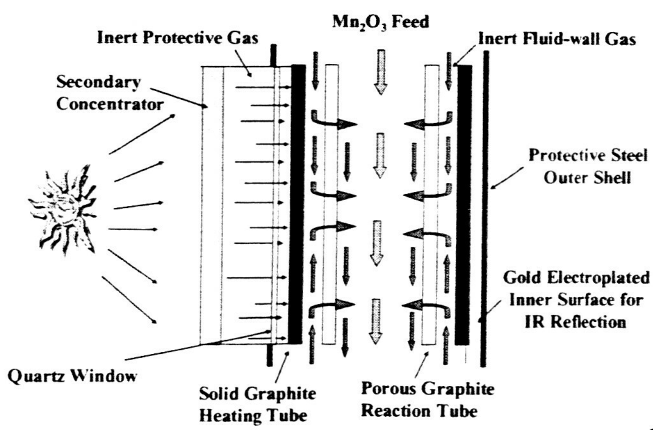
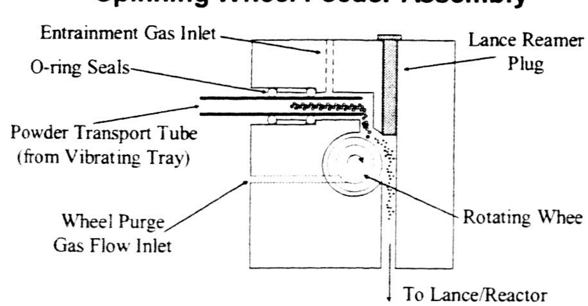




**Figure 19. Proposed Improved-efficiency So Fluid-wall Aerosol Reactor for $Mn_2O_3$ Dis**

**Figure 20.**

**Spinning Wheel Feeder Assembly**




**Key – Mechanical shear (dispersion of feed solids) is controlled independently of gas flow (i.e. residence time)**

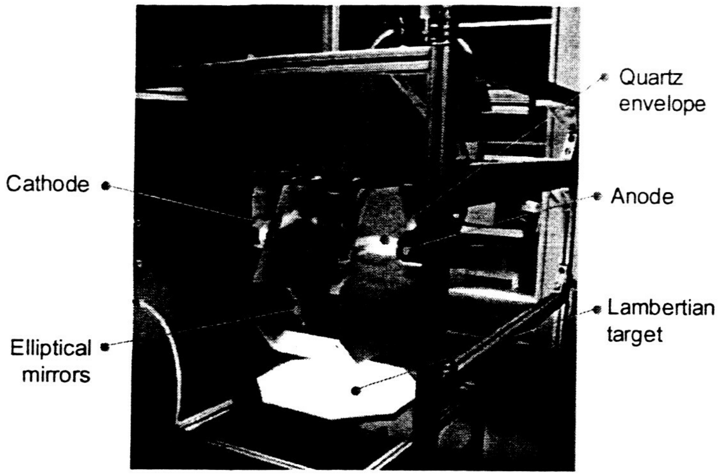
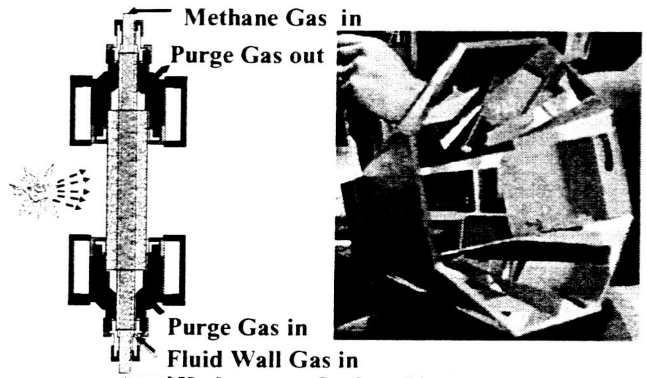
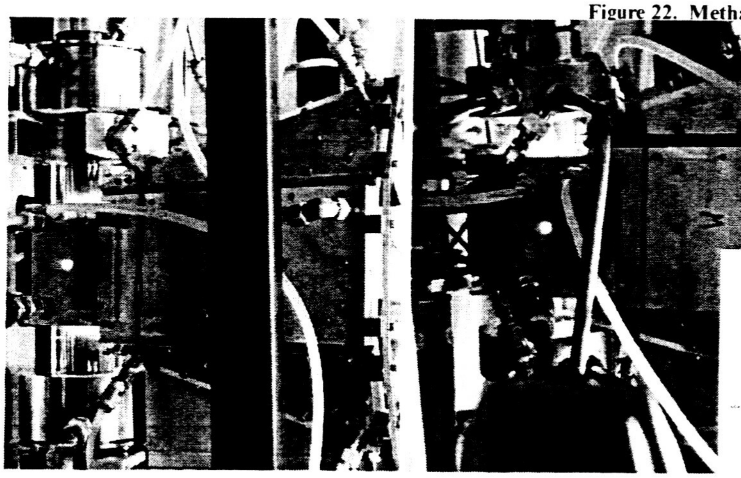



**Figure 21. Solar Simulator at ETH-Zurich**




(a) Without secondary (b) With Secondary Concentrator

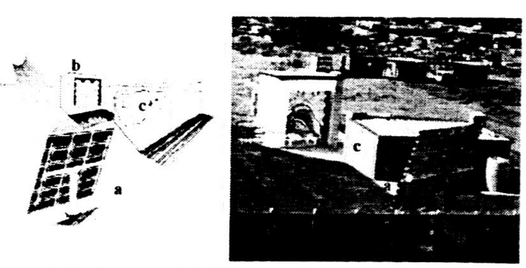
Figure 22. Methane Splitting Solar-thermal Fluid-wall Reactor



(a) 1350 °C (1623 K) (b) 1650 °C (1923 K)

**Figure 23. Graphite Fluid-wall Reactor at NREL**

Figure 24. 10 kW High – Flux Solar Furnace Facility at NREL




a) Heliostat b) Primary Concentrator c) Reactor